UTILITY PATENT APPLICATION TRANSMITTAL

(Only for new nonprovisional applications under 37 CFR 1.53(b))

Attorney Docket No.	OPT 32U	Total Pages	21
First Named Inventor or Application Identifier	SMALSER, P. J.		
Express Mail Label No.	EJ047402687US		

APPLICATION ELEMENTS

See MPEP chapter 600 concerning utility patent application contents.

ADDRESS TO: Assistant Commissioner for Patents, Box Patent Application, Washington, DC 20231

1. ☐ Fee Transmittal Form *(Submit an original, and a duplicate for fee processing)*
2. ☑ Specification [Total Pages 10] *(preferred arrangement set forth below)*
   - Descriptive title of the Invention
   - Cross References to Related Applications
   - Statement Regarding Fed sponsored R & D
   - Reference to Microfiche Appendix
   - Background of the Invention
   - Brief Summary of the Invention
   - Brief Description of the Drawings *(if filed)*
   - Detailed Description
   - Claim(s)
   - Abstract of the Disclosure
3. ☑ Drawing(s) *(35 USC 113)* [Total Sheets 1]
4. Oath or Declaration [Total Pages 3]
   - a. ☑ Newly executed (original or copy)
   - b. ☐ Copy from a prior application (37 CFR 1.63(d)) *(for continuation/divisional with Box 17 completed)* *[Note Box 5 below]*
     - i. ☐ DELETION OF INVENTOR(S) Signed statement attached deleting inventor(s) named in the prior application, see 37 CFR 1.63(d)(2) and 1.33(b).
5. ☐ Incorporation By Reference *(useable if Box 4b is checked)* The entire disclosure of the prior application, from which a copy of the oath or declaration is supplied under Box 4b, is considered as being part of the disclosure of the accompanying application and is hereby incorporated by reference therein.
6. ☐ Microfiche Computer Program *(Appendix)*
7. Nucleotide and/or Amino Acid Sequence Submission *(if applicable, all necessary)*
   - a. ☐ Computer Readable Copy
   - b. ☐ Paper Copy (Identical to computer copy)
   - c. ☐ Statement verifying identity of above copies

ACCOMPANYING APPLICATION PARTS

8. ☑ Assignment Papers (cover sheet & document(s))
9. ☐ 37 CFR 3.73(b) Statement *(when there is an assignee)* ☐ Power of Attorney
10. ☐ English Translation Document *(if applicable)*
11. ☐ Information Disclosure Statement (IDS)/PTO-1449 ☐ Copies of IDS Citations
12. ☐ Preliminary Amendment
13. ☑ Return Receipt Postcard (MPEP 503) *(Should be specifically itemized)*
14. ☑ Small Entity Statement(s) ☐ Statement filed in prior application, Status still proper and desired
15. ☐ Certified Copy of Priority Document(s) *(if foreign priority is claimed)*
16. ☑ Other: checks #3750 $40 ; #3751 $380

17. If a CONTINUING APPLICATION, *check appropriate box and supply the requisite information:*
    ☐ Continuation ☐ Divisional ☐ Continuation-in-part (CIP) of prior application No: _____/_____

18. CORRESPONDENCE ADDRESS

☐ Customer Number or Bar Code Label *(Insert Customer No. or Attach bar code label here)* or ☒ Correspondence address below

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PATENT

Attorney's Docket No. OPT 324

Applicant or Patentee: _____

Serial or Patent No.: 0 / _____

Filed or Issued: _____

For: _____

VERIFIED STATEMENT (DECLARATION) CLAIMING SMALL ENTITY STATUS (37 CFR 1.9(f) and 1.27(c))—SMALL BUSINESS CONCERN

I hereby declare that I am

- ☐ the owner of the small business concern identified below:
- ☒ an official of the small business concern empowered to act on behalf of the concern identified below:

NAME OF CONCERN OCEAN POWER TECHNOLOGIES, INC.

ADDRESS OF CONCERN 1590 REED ROAD, BUILDING A, SUITE 1
PENNINGTON, N.J. 08534

I hereby declare that the above identified small business concern qualifies as a small business concern as defined in 13 CFR 121.3-18, and reproduced in 37 CFR 1.9(d), for purposes of paying reduced fees under Section 41(a) and (b) of Title 35, United States Code, in that the number of employees of the concern, including those of its affiliates, does not exceed 500 persons. For purposes of this statement, (1) the number of employees of the business concern is the average over the previous fiscal year of the concern of the persons employed on a full-time, part-time or temporary basis during each of the pay periods of the fiscal year, and (2) concerns are affiliates of each other when either, directly or indirectly, one concern controls or has the power to control the other, or a third-party or parties controls or has the power to control both.

I hereby declare that rights under contract or law have been conveyed, to and remain with the small business concern identified above with regard to the invention, entitled
PROTECTION ARRANGEMENT FOR NATURAL ENERGY....SYSTEMS

by inventor(s) PAUL J. SMALSER, CHARLES B. CARROLL

described in

- ☒ the specification filed herewith.
- ☐ application serial no. 0 / _____, filed _____.
- ☐ patent no. _____, issued _____.

If the rights held by the above identified small business concern are not exclusive, each individual, concern or organization having rights to the invention is listed below* and no rights to the invention are held by any person, other than the inventor, who could not qualify as a small business concern under 37 CFR 1.9(d) or by any concern which would not qualify as a small business concern under 37 CFR 1.9(d) or a nonprofit organization under 37 CFR 1.9(e).

*NOTE: *Separate verified statements are required from each named person, concern or organization having rights to the invention averring to their status as small entities. (37 CFR 1.27).*

NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

NAME _____

ADDRESS _____

☐ INDIVIDUAL ☐ SMALL BUSINESS CONCERN ☐ NONPROFIT ORGANIZATION

I acknowledge the duty to file, in this application or patent, notification of any change in status resulting in loss of entitlement to small entity status prior to paying, or at the time of paying, the earliest of the issue fee or any maintenance fee due after the date on which status as a small business entity is no longer appropriate. (37 CFR 1.28(b)).

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful false statements may jeopardize the validity of the application, any patent issuing thereon, or any patent to which this verified statement is directed.

NAME OF PERSON SIGNING Charles F. Dunleavy

TITLE OF PERSON OTHER THAN OWNER Vice President, Finance

ADDRESS OF PERSON SIGNING 1590 Reed Road

Pennington NT 08534

SIGNATURE Charles F. Dunleavy Date 10/27/99

Protection Arrangement for Natural Energy Power Generation Systems

This application claims the benefit of provisional patent application 60/105,990 filed October 28, 1998.

Background of the Invention

This invention relates to the generation of electrical power from natural sources of energy, e.g., ocean waves, and particularly to the protection of the power generating system during conditions of excessively high levels of input energy, e.g., during ocean storms, while still operating the system for producing power.

One technique for protecting a power generating system during excessively high levels of input energy is simply to shut the system down; e.g., submerge a floating system normally responsive to the passage of ocean waves sufficiently deeply to be isolated from the surface storm conditions. A problem with this, however, is that power production is lost while the system is shut down.

Solutions are known where the power generating systems are only partially shut down; e.g., a system normally floating freely on the surface of an ocean is submerged beneath the surface but at a depth still responsive to the over-passing waves. Generally, however, such partial shut down solutions are complex and relatively slow operating.

The present invention provides a protection arrangement which is simple, inexpensive and quickly responsive to changing circumstances.

Summary of the Invention

In a power generating system using an electrical generator for generating electrical output power from the system, protection against excessive input energy levels is obtained by increasing the current output from the generator to an amount greater than that would "normally" otherwise be generated at the generator output in response to the increased energy input. The higher than normal output current changes the system operating efficiency and increases the mechanical impedance of the system to a level higher than would be present if the "normal" output current were being generated. The higher system mechanical impedance thus "stiffens" the system against the increased input energy, thus preventing for example, excessively high generator speeds of rotation. The system, while now operating at a less than optimum operating efficiency, continues to generate power.

Description of the Drawing

The sole drawing figure is a schematic illustration of a power generating system in accordance with the invention.

Description of Preferred Embodiments of the Invention

With reference to the drawing, a power generating system is illustrated for converting, by way of one example of use of the invention, energy contained in waves on the surface of an ocean to useful electrical power. Many such systems are known. Herein, quite simply, a float 10 vertically oscillates in response to passing waves for driving a hydraulic cylinder 12 for pressurizing a fluid for driving a hydraulic motor 14 for driving an electrical generator 16 for

generating electrical energy for transfer to an electrical load 18, e.g., an a.c. to d.c. rectifier for charging a storage battery.

Normally, the problem is to maximize the power output from the system, and the system is designed for operation at maximum possible efficiency.

As known, various energy converters, such as ocean wave and wind and water flow energy converters operate most efficiently when they are driving a power generating system whose impedance is matched to the configuration of the energy converter, and to the natural energy level present. The impedance can be thought of as the ratio of the force required to drive a system to the velocity produced in the driven system. A low impedance system will move rapidly when a small force is applied, whereas a high impedance, or stiff, system will move slowly even when a large force is applied. The power delivered to a system is the product of force and velocity (e.g., Newtons times meters per second (Nm/s) equals Watts of power). Drive systems for natural energy sources are normally designed and controlled to produce the maximum product of force and velocity delivered as power from the entire system.

During times of storms or other events, there can be very large amounts of natural energy impinging on a wave or flow energy converter. When this high natural energy is converted to mechanical energy, the system can be damaged or destroyed. For example, a piston with a physically defined stroke can be driven through its end stops, or a turbine can be driven fast enough that it is structurally damaged, or that its attached generator produces voltages that exceed the limits of the generator or its circuitry.

This disclosed innovation prevents system damage due to storms, while still producing power, by adjusting the impedance of the system from the optimum system efficiency values to high levels that impede the production of large

motions or speeds. The technique for system impedance adjustment is to vary the electrical load of the electric power generator. These higher levels of system impedance do not just absorb the natural energy less efficiently, they greatly reduce the conversion efficiency of the natural energy converter. This reduction in natural energy conversion efficiency can easily be a factor of ten. This greatly reduces the level of mechanical energy delivered to the drive system and prevents damage. This disclosed system is intelligent and only reduces the overly high energy available to acceptable levels while continuing to generate useful power.

The electric power generated by an electromagnetic generator is comprised of volts (potential) and amps (current). The product of the voltage times the amperage is the power in Watts (P = VxA). Thus, 100 Watts of power could be comprised of 100 volts times 1 amp, or 1 volt times 100 amps. With electromagnetic generators, the voltage produced is directly related to the generator's speed of rotation. The amount of current that can be produced at that voltage is directly related to the torque applied to the generator's shaft. These properties provide the opportunity for the generator's electronic circuitry to control the generator's mechanical impedance as seen at its drive shaft. As an example, assume a generator is being driven with a shaft speed of 5 Hertz (Hz), and is producing 100 volts while 1 amp is being drawn from the generator by its power circuitry. The generator is producing 100 Watts. The equation for mechanical power in a rotary device is P = 2 Tf, where:

P = mechanical power in Watts

T = the torque applied to the shaft in Nm

f = frequency of shaft rotation in Hz

In this case, 100 = 2 T5, and therefore the torque required at the shaft is at least T = 3.18 Nm. The reason that the term "at least" is used is that a generator

is not 100% efficient in converting torque into electrical current. However, the torque and current are directly related in a particular generator operating under particular conditions, and the principles of operation herein disclosed remain true for all typical generators. Therefore, in the present illustrative example, it is accepted that the torque-to-current coefficient of the generator is T = 3.18 Nm/amp.

In this example, if the power electronics circuit begins to draw 2 amps from the generator, the immediate power produced would be 200 Watts. If the natural energy source is providing sufficient energy, the generator speed can remain at 5 Hz, the torque input will be 6.36 Nm, and the power generated will remain at 200 Watts. This situation is good from an economic point of view, but does not provide over-stroke protection. If the power electronics circuit begins to draw 3 amps from the generator, the immediate power produced would be 300 Watts and the torque required would be T = 3x3.18 = 9.54 Nm. If the natural energy source is not providing sufficient energy to produce this torque, the generator speed cannot remain at 5 Hz. Assume, for example, that the speed decreases to 4 Hz. In this case the power generated would be P = 2 (3x3.18)4 = 240 Watts. More power is being generated and the system has slowed down. Thus, the chance of over stroking or over speeding has been reduced.

Now assume that the power electronics begins to draw 4 amps from the generator, and that this is at the limits of torque or force that the natural energy converter can extract from the environment. In this case, the speed will decrease significantly, for example to 1 Hz. The power generated would be P = 2 (4x3.18)1 = 80 Watts. The actual power delivered may be even lower due to increased heating losses in the generator windings caused by the increased current flow. However, power is still being generated as the system motion is greatly

retarded. Further increases in the current drawn from the generator would increase the systems impedance mismatch with the energy environment to the point that the drive stops moving and energy can no longer be converted. When it is safe to allow the system to move again, for instance when a wave is at a peak or trough and no vertically moving energy is available, the impedance can be decreased to provide power generation during the ensuing up or down wave motion. The electrical load impedance can be changed very rapidly as compared to the speed of the mechanical parts of the system.

The power generating or absorbing capacity of the generator and electronic circuits does not need to equal the power available to the natural energy converter during a storm. This would not be economical since the full power capacity would be used only rarely. The power capacity needs only to be sufficient to allow higher than optimum electric current to be drawn which increases the system impedance and hinders or essentially stops the energy converter from collecting natural power.

To provide intelligent control of the over-stroke protection technology, a sensor (e.g., shown as 80 in the drawing) is needed to detect the position of the stroking section of the energy converter. In the case of a rotary driven device such as a turbine, a sensor that measures speed is needed, for a linearly driven device, e.g., an hydraulic cylinder, a cylinder piston pivoting sensor is needed. Such sensors would normally be present in known power generating systems to provide operational information and, for use with the present invention, the outputs from such sensors are also communicated to the over-stroke controller. In a simple control strategy, an over-stroke control computer 22 constantly monitors the stroke position or system rotary speed and does not take action unless the measured values exceed a pre-selected value. When the stoke position

or rotary speed exceeds the pre-selected value, the over-stroke controller significantly increases the system impedance. If the next sensor readings are still too high, the impedance is again increased. This procedure is repeated until the sensor readings are within the acceptable range. If the rotary speed or position does not increase, the over-stroke control returns to the monitoring mode and the regular (known) power conversion circuit continues to operate the system.

A somewhat more sophisticated strategy for linear motion over-stroke or over-speed control requires calculating the rate of increase of stroke speed or rotary speed. This does not require a sensor in addition to the aforementioned sensors because the difference between sequential readings taken in fixed time steps indicates whether the system is speeding up or not. This speed calculation combined with the absolute position or speed allows the over-stroke control to chose larger or smaller increments of impedance increase to effect a smoother and more efficient control strategy. For example, if the stroke is approaching the allowable stroke limit but is not moving too fast, and is slowing down, a small amount of impedance increase is applied. This keeps the generator operating in an efficient range, and brings the system to a smooth stop. However, in an extreme condition, when the stroke is approaching the allowable stroke limit at a high rate of speed, and the speed is increasing, a large amount of impedance increase is applied. Also, the speed sensor is quickly checked again and the impedance increased again if necessary. This situation will produce inefficient power generation for a short period, and an abrupt braking of the stroke motion. However, power is still generated and the stroke is prevented from mechanically hitting its end-stop and damaging the system.

In the case of rotary motion and the use of the foregoing described more sophisticated control strategy, a larger impedance increase is added to the system

if the speed is increasing rapidly as it approaches the speed limit than is added if the speed is slowly increasing as it approached the speed limit.

The described over-stroke/over-speed control approach does not cause undue wear on the system since excess energy is absorbed electrically and not mechanically. Also, it does not absorb all of the excess natural energy but rather causes the natural energy converter to become inefficient and to transfer only a small portion of the excess energy to the drive system.

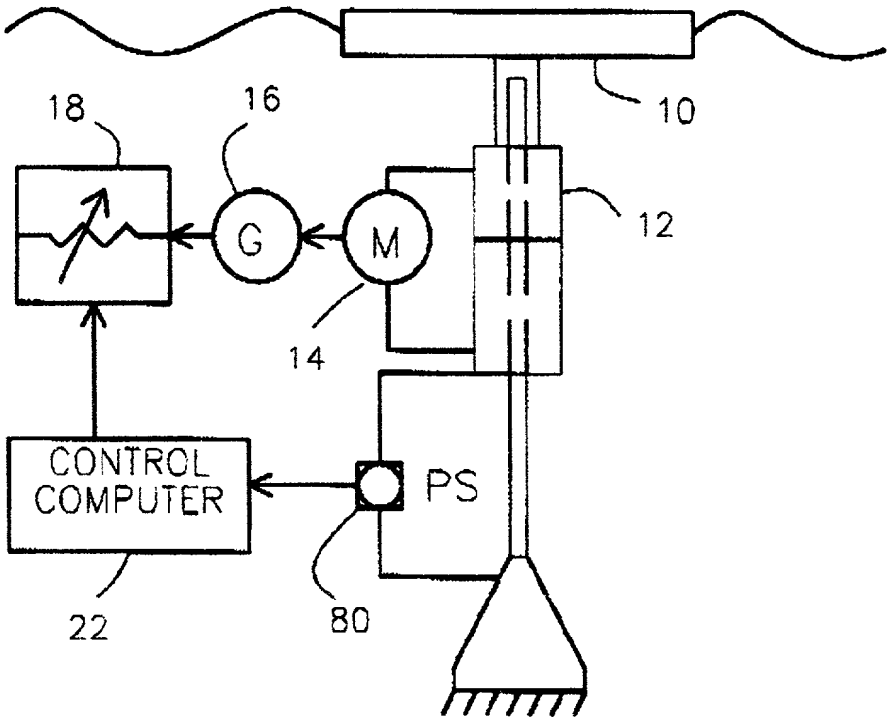
What is claimed is:

1. A method of operating a system for generating electrical power from a source of input energy occurring at variable rates including first rates at which the input energy can be safely captured at high energy conversion efficiencies and second rates in excess of the first rates and at which capture of the input energy at the high energy conversion efficiencies is likely to cause mechanical damage to the system, the method comprising collecting, with a power collecting mechanism, the input energy when present at said first rates and driving an electrical generator with said collected energy for generating and transferring electrical energy, to an electrical load, at a high input energy conversion efficiency corresponding to a first mechanical impedance presented to the power collecting mechanism and, in response to the input energy arriving at said second rates, varying the impedance of said load for increasing the output current from the generator for reducing the input energy conversion efficiently of the generator for increasing the mechanical impedance of the generator.

2. A method of operating a system for generating electrical power from a source of input energy arriving at variable rates comprising capturing the input energy with a mechanism for converting the input energy to mechanical energy for driving an electrical generator for generating and transferring electrical energy to an electrical load, and, when the input energy exceeds a preselected rate, varying the impedance of the load for increasing the current to the load for decreasing the energy conversion efficiency of the generator for increasing the mechanical impedance of the generator presented to the energy capturing mechanism.

Abstract of the Disclosure

Protection against damage caused by excessively high input energies, e.g., from ocean storms, is provided in energy converting systems by, in response to the detection of excessively high input energies, changing the electrical impedance of the electrical load to which power from an electrical generator is being delivered for increasing the generator output current for reducing the power converting efficiency of the generator. This increases the mechanical impedance presented by the generator to the source of input energy for reducing the motion producing effect of the input energy.



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DECLARATION FOR UTILITY OR DESIGN PATENT APPLICATION (37 CFR 1.63)

☒ Declaration Submitted with Initial Filing OR ☐ Declaration Submitted after Initial Filing (surcharge (37 CFR 1.16 (e)) required)

Attorney Docket Number	OPT 32 U
First Named Inventor	SMALSER, P. J.
COMPLETE IF KNOWN	
Application Number	/
Filing Date	OCT. 28, 1999
Group Art Unit	
Examiner Name	

As a below named inventor, I hereby declare that:

My residence, post office address, and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on the invention entitled:

PROTECTION ARRANGEMENT FOR NATURAL ENERGY POWER GENERATION SYSTEMS

(Title of the Invention)

the specification of which
☒ is attached hereto
OR
☐ was filed on (MM/DD/YYYY) _____ as United States Application Number or PCT International Application Number _____ and was amended on (MM/DD/YYYY) _____ (if applicable).

I hereby state that I have reviewed and understand the contents of the above identified specification, including the claims, as amended by any amendment specifically referred to above.

I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56.

I hereby claim foreign priority benefits under 35 U.S.C. 119(a)-(d) or 365(b) of any foreign application(s) for patent or inventor's certificate, or 365(a) of any PCT international application which designated at least one country other than the United States of America, listed below and have also identified below, by checking the box, any foreign application for patent or inventor's certificate, or of any PCT international application having a filing date before that of the application on which priority is claimed.

Prior Foreign Application Number(s)	Country	Foreign Filing Date (MM/DD/YYYY)	Priority Not Claimed	Certified Copy Attached? YES	NO
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐
			☐	☐	☐

☐ Additional foreign application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto:

I hereby claim the benefit under 35 U.S.C. 119(e) of any United States provisional application(s) listed below.

Application Number(s)	Filing Date (MM/DD/YYYY)	
60/105,990	10/28/1998	☐ Additional provisional application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

Burden Hour Statement: This form is estimated to take 0.4 hours to complete. Time will vary depending upon the needs of the individual case. Any comments on the amount of time you are required to complete this form should be sent to the Chief Information Officer, Patent and Trademark Office, Washington, DC 20231. DO NOT SEND FEES OR COMPLETED FORMS TO THIS ADDRESS. SEND TO: Assistant Commissioner for Patents, Washington, DC 20231.

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DECLARATION — Utility or Design Patent Application

I hereby claim the benefit under 35 U.S.C. 120 of any United States application(s), or 365(c) of any PCT international application designating the United States of America, listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in the prior United States or PCT international application in the manner provided by the first paragraph of 35 U.S.C. 112, I acknowledge the duty to disclose information which is material to patentability as defined in 37 CFR 1.56 which became available between the filing date of the prior application and the national or PCT international filing date of this application.

U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

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As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number OR ☐ Registered practitioner(s) name/registration number listed below → PTO Customer Number Bar Code Label here

Name	Registration Number	Name	Registration Number

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

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I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of Sole or First Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle if any)	Family Name or Surname
Paul J	Smalser

Inventor's Signature	x Paul J. Smalser					Date	10/27/98
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☐ Additional inventors are being named on the ____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto

Please type a plus sign (+) inside this box → ☐

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DECLARATION — Utility or Design Patent Application

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U.S. Parent Application or PCT Parent Number	Parent Filing Date (MM/DD/YYYY)	Parent Patent Number (if applicable)

☐ Additional U.S. or PCT international application numbers are listed on a supplemental priority data sheet PTO/SB/02B attached hereto.

As a named inventor, I hereby appoint the following registered practitioner(s) to prosecute this application and to transact all business in the Patent and Trademark Office connected therewith: ☐ Customer Number OR ☐ Registered practitioner(s) name/registration number listed below → Place Customer Number Bar Code Label here

Name	Registration Number	Name	Registration Number
Michael Y Epstein	21186		

☐ Additional registered practitioner(s) named on supplemental Registered Practitioner Information sheet PTO/SB/02C attached hereto.

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Telephone	(908)359-8453
Fax	(908)359-1493

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true; and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under 18 U.S.C. 1001 and that such willful false statements may jeopardize the validity of the application or any patent issued thereon.

Name of 2nd Inventor: ☐ A petition has been filed for this unsigned inventor

Given Name (first and middle if any)	Family Name or Surname
Charles B	Carroll

Inventor's Signature	x Charles B. Carroll					Date	10/27/99
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Post Office Address	27 Galston Dr.						
Post Office Address							
City	Trenton	State	NJ	ZIP	08691	Country	USA

☐ Additional inventors are being named on the ____ supplemental Additional Inventor(s) sheet(s) PTO/SB/02A attached hereto